Can Transport Policies Contribute to the Mitigation Potential and Cost of Stringent Climate Change Targets?

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Limiting warming to below 2°C and 1.5°C is ambitious and undoubtedly a very challenging task. Achieving 2°C and 1.5°C goals requires more rapid and profound decarbonization of the energy supply and a high carbon price, which will generate mitigation costs such as GDP and welfare loss. Because the transport sector represents a quarter of global CO_2 emissions and is recognized to be one of the main causes of global warming, the decarbonization in the transport sector is supposed to contribute to the achievement of the stringent climate mitigation targets.

To achieve a better understanding of the role of transport policies in achieving climate change targets, the main purpose of this research is to investigate the interaction between transport policies, global dynamics of transport demand volume, mitigation potential, and the cost of meeting the goal of limiting warming to below 2°C and 1.5°C. To capture the interplay between the transport sector and the macroeconomy, a global transport model, AIM/Transport, coupled with AIM/CGE has been used to overcome the shortcomings of individual CGE and transport models. By doing this, both the traveler's mode choice and technology details, and an interactive analysis on mitigation potential and cost of transport policies, can be incorporated into a projection of global passenger and freight transport activities.

Methodology

A transport model, AIM/Transport, is developed to project the global passenger and freight transport demand for different modes and technologies and transport-related emissions, incorporating transport mode choice and technological details. AIM/Transport is coupled with a global computable general equilibrium model AIM/CGE to capture the interactive mechanism between the transport sector and the macroeconomy. AIM/CGE is also a one-year interval recursive-type, dynamic, general equilibrium model that covers all regions of the world and consists of 42 industrial classifications. An iterative method was used to integrate AIM/CGE and AIM/Transport. This loop continues until the energy consumptions computed in AIM/CGE and AIM/Transport are equal. The iterative procedure helps refine the transport representation in AIM/CGE, based on detailed AIM/Transport information.

We structured the scenario framework in three dimensions. For the GDP and population, shared socioeconomic pathways 2 (SSP2) estimates were employed as default values for GDP and population in AIM/Transport. The second dimension is the climate policy dimension, denoted by "BaU", "2D" and "1.5D". In the "BaU" scenario, no climate mitigation efforts are assumed, while a carbon price is imposed in the "2D" and "1.5D" scenarios to approximately meet emission radiative forcing targets of 2.7 W/m^2 and 1.9 W/m^2 in 2100 to limit global warming to 2° and 1.5°, respectively. The third dimension is the transport policy for simulating how different transport factors and policy interventions affect the mitigation potential and cost. We selected representative transport policies from technological and behavioral aspects including energy efficiency improvement (Ei_High), vehicle technological innovation (Tech_Innovation), mass transit-oriented transport development (Mass_Transit), vehicle occupancy (Occu_High), and low-carbon scenario (Low_Carbon) which was applied to combine technological and behavioral issues.

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Results

Scenario simulation results proved that CO_2 emissions can be reduced by implementing transport policies such as energy efficiency improvements, vehicle technological innovations, mass transit-

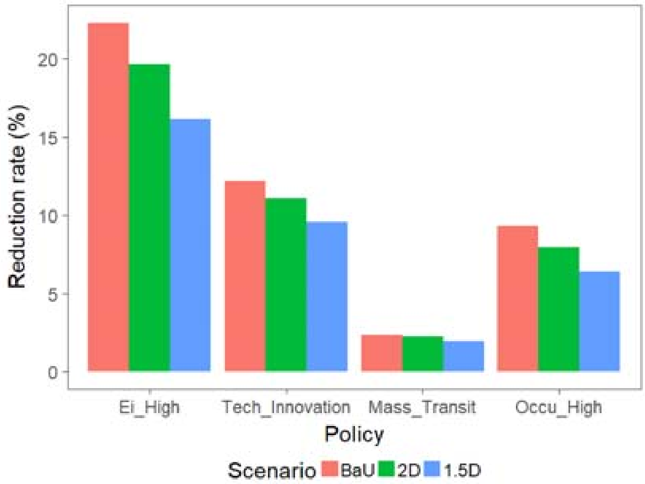

Figure 1. Impacts of transport policies on reduction potential of cumulative emissions

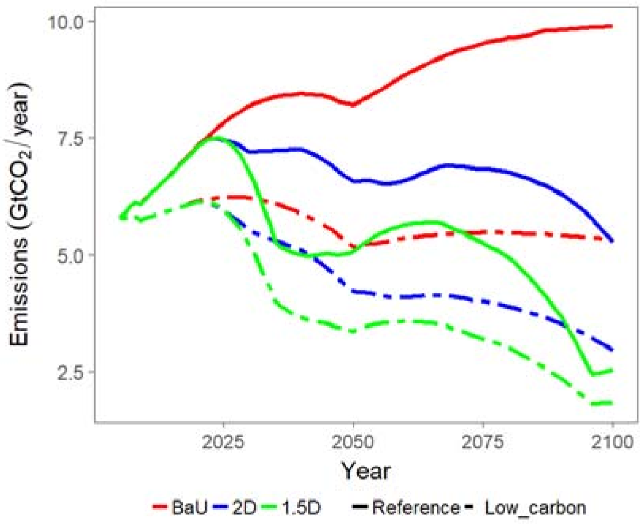

Figure 2. Emissions trajectories during 2005–2100

oriented transport developments, and increasing the occupancy rate of cars in the BaU, 2°C, and 1.5°C scenarios. In summary, Ei_High, Tech_Innovation, and Occu_High have significant impacts on emission reduction, whereas Mass_Trasnsit has relatively weak effects (figure 1). As shown in figure 2, with the implementation of a low-carbon transport policy, the 2°C scenario generated an emission trajectory similar to the 1.5°C scenario, without any transport policy, implying that transport policies can help achieve the 1.5°C goal only by applying the carbon tax rate of the 2°C scenario. Maximum emission reduction can be achieved with low-carbon transport strategies combining both technological and behavioral policies, indicating that the synergistic effect between policies in different sectors needs to be considered for maximum potential emission reduction.

Although road transportation theoretically could become completely electrified over the coming decades, it is still unclear whether there is the prospect of electrified aviation and shipping. Unless all fossil fuels would be replaced by biofuels, the passenger aviation and freight sectors still remain dependent on fossil fuels. The technological and economic optimization leads to there being ongoing use of fossil fuels in the transport sector, mainly for international aircraft, and that negative emissions are thus required to balance this usage in order to meet the temperature goals.

Figure 3 shows that carbon price, GDP loss rate, and welfare loss rate can be reduced in the Low_Carbon scenario. The GDP and welfare loss rate can be lowered because the low-carbon transport policies are conducive to decreasing the CO_2 emissions in the transport sector, which helps alleviate the economic losses generated by stringent carbon tax imposition. Furthermore, the values of the reduction in GDP loss rate in the 1.5°C scenario are higher than those in the 2°C scenario after 2030, implying that the contribution to the reduction in GDP loss is relatively more significant in the 1.5°C target. The degree of contribution of transport policies is more effective for stringent climate change targets.

Discussion and conclusion

The integration of the transport model and CGE model can enrich transport representation in an integrated assessment model and capture mode and technological factors. Simulation results show that transport policy interventions alter global transport-related energy consumption composition and emission trajectories. This study therefore provides a comprehensive and multidimensional policy tool for long-term decision making in transport decarbonization. Implementation of transport policies combining technological innovation and changes in transport behaviors is required to achieve both the 2°C and 1.5°C goals.

The policy with the highest priority is to strongly promote fully battery electric-powered vehicles to achieve the goal of deep decarbonization in the transport sector, though social transformations such as lifestyle change and low-carbon urban reorganization could be effective as supplementary policy tools. Balanced technological and social transformations can mitigate risks that may not be fully addressed via technological innovation alone, for developing an energy-efficient decarbonized transport system.

Because the feedback between the AIM/Transport and AIM/CGE models helps detect the effects of transport sector dynamics on the macroeconomy, these analyses convince us that transport policies provide an effective contribution to modifying the mitigation cost. Because this methodology of transport modeling overcomes the limitations of linking the CGE model and the transport model,

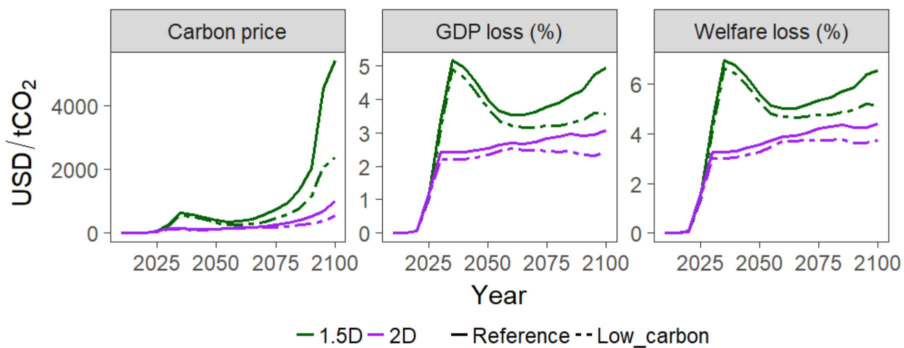

Figure 3. Mitigation cost metrics for the 2°C and 1.5°C targets

it may be used by transport planners to analyze how mitigation options would affect the dynamics of the macroeconomy. Interestingly, the greater effectiveness of transport policies was well demonstrated in the 1.5°C scenario, indicating that the transport sector deserves more attention for achieving stringent climate change mitigation targets.

Policy implications can be drawn from the scenario simulations. First, the liquid fuel savings can be realized directly by the deployment of hybrid vehicles, which is likely to become a significant fraction of new vehicle sales in the interim before becoming fully electric. Then substantial numbers of fully battery electric-powered vehicles can be strongly promoted to achieve the goal of deep decarbonization in the transport sector. Second, it is necessary to establish a public transit system with better accessibility, security, and comfort to influence households' preference on transport modes. Specifically, investing in public transport infrastructure such as dedicated corridors for buses and railways, and high-speed trains such as maglev, can assist in shifting more travelers from carbon-intensive modes to a transit-oriented movement. Third, decarbonization in the transport sector requires innovative policy strategies for lifestyle transformations. The government needs to launch a scheme to promote car sharing and carpooling, to increase the car occupancy rate and cut the number of commuters.

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